Do Capital Requirements Make Banks Safer? Evidence from a Quasi-natural Experiment

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ABSTRACT

We use the EBA capital exercise of 2011 as a quasi-natural experiment to investigate how capital requirements affect various measures of bank solvency risk. We show that, while regulatory measures of solvency improve, non-regulatory measures indicate a deterioration in bank solvency in response to higher capital requirements. The decline in bank solvency is driven by a permanent reduction in banks' market value of equity. This finding is consistent with a reduction in bank profitability, rather than a repricing of bank equity due to a reduction of implicit and explicit too-big-too-fail guarantees. We then discuss alternative policies to improve bank solvency.

Keywords: Capital requirements, regulation, banks, risk, Basel III.
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I. Introduction

The financial crisis of 2007 and 2008 precipitated broad regulatory reforms intended to make the financial system more robust. At the heart of these reforms were efforts to strengthen regulatory capital buffers of banks. For instance, Basel III increased the minimum Tier 1 capital requirement from 4% to 6%, with substantial scope for further capital buffers. Increased buffer requirements have made banks substantially more robust when considering regulatory measures of bank capitalization. They have lead policy-makers to conclude that the financial system is significantly more resilient to fluctuations in asset values today, compared to before the crisis (Yellen, 2018). Empirical work on market-based measures of systemic risk has found evidence for a decline in systemic fragility since the U.S. financial crisis and the European sovereign debt crisis, respectively (see Engle, 2018, for a recent survey on systemic risk). At the same time, the view that risk has decreased on all fronts after the financial crisis is not unanimously accepted in the literature. For example, Sarin and Summers (2016) show descriptive evidence suggesting that, based on *non-regulatory measures of risk*, such as volatility and systematic risk, banks are as risky or even *riskier* compared to before the crisis. Hence, over ten years after the financial crisis, there is still substantial uncertainty and debate regarding the effectiveness of capital requirements in terms of reducing bank insolvency risk.

The goal of our paper is to inform this debate by investigating *how* and *why* capital requirements affect a large set of bank risk measures. Most importantly, we focus on both the Core Tier 1 capital ratio as a regulatory measure and other non-regulatory measures in order to get a complete picture of the relationship between capital requirements and bank solvency. Our non-regulatory measures consist of accounting-based metrics (the inverse of the z-score), market-based bank-level metrics (systematic risk, stock return volatility, market leverage, and Value-at-Risk) and systemic risk measures (Marginal Expected Shortfall (Acharya et al., 2017), SRISK (Brownlees and Engle, 2017), and ΔCOVAR (Adrian and Brunnermeier, 2016)).[1]

Identifying the causal effects of higher capital requirements on risk is challenging. Given that capital requirements are meant to address insolvency risk, there is a strong concern of reverse causality running from bank risk to capital. Moreover, due to confounding factors affecting both

[1]Many of these non-regulatory measures, such as market leverage, are shown to be a better predictor of bank solvency compared to regulatory measures (Haldane and Madouros, 2012).

policy-makers' decisions to increase capital requirements and a bank's risk, the estimated effect of higher capital requirements on a bank's risk from a simple OLS regression is likely to be biased. To identify the causal effect of higher capital requirements on bank risk, we therefore exploit the 2011 capital exercise conducted by the European Banking Authority (EBA) as a quasi-natural experiment, which led to an increase in the Core Tier 1 capital requirement to 9% for a subset of European banks ("EBA banks"). Due to the selection rule for assigning whether a bank would face an increase in capital requirements, treatment status for banks was based on observables, and there was substantial variation in treatment status conditional on these observables.

Our paper is inspired by Gropp et al. (2019). They exploit the 2011 EBA capital exercise as a quasi-natural experiment to investigate how banks adjust to higher capital requirements. They document that banks participating in the EBA capital exercise increase their CT1 ratios primarily by lowering risk-weighted assets. Our paper relates to their paper by taking an additional step and asking what this adjustment implies for bank risk. While lower risk-weighted assets can imply lower risk, some evidence - especially prior to the financial crisis - could suggest otherwise due to, for instance, underreporting of risk (see, e.g., Engle, 2018). Moreover, by reallocating their portfolio, bank charter value, which ultimately is an important determinant for many risk-metrics, could be affected (Sarin and Summers, 2016).

We exploit the EBA capital exercise by employing a flexible difference-in-differences approach, where we compare our risk metrics for EBA banks with non-EBA banks before, during, and after the EBA capital exercise. We combine data from several sources to perform our analysis. Specifically, we combine quarterly balance sheet items with market-based data on stock prices and dividend payouts as well as information on bank credit ratings to arrive at a more detailed picture of the differential effects of higher capital requirements.

Our findings can be summarized in terms of two broad conclusions. The first conclusion is that the overall effect of capital requirements on bank risk crucially depends on whether we consider regulatory or non-regulatory risk measures. Specifically, consistent with Gropp et al. (2019), we show that banks respond to higher capital requirements by reducing risk-weighted assets and that this improves regulatory measures of bank solvency. The picture, however, is very different when we consider non-regulatory measures of bank-level risk. None of the non-regulatory measures we consider improve as a consequence of the increase in capital requirements. In fact, according to several measures, banks become *less safe* as capital requirements increase. Specifically, (the absolute value of) Value-at-Risk, the inverse z-score, systematic risk, marginal expected shortfall, market-based leverage ratio, and SRISK all *increase* following the tightening of capital requirements. Hence, based on these non-regulatory measures, the EBA capital exercise failed in terms of increasing bank solvency.

We then move on to explore why this is the case. Our second conclusion is that a decline in the market capitalization of treated banks drives the increase in non-regulatory risk measures. We explore the underlying reasons for this. Specifically, we hypothesize that a decrease in market capitalization can arise either due to a reduction in profitability, changes in dividend policies, or a decline in the perceived likelihood of a public bailout. Understanding which of these channels are driving the results is crucial for the overall welfare implications of higher capital requirements. If the market capitalization of EBA banks decreases due to lower bailout probabilities, the decline in market capitalization and associated increase in non-regulatory risk measures can be welfare improving. We find, however, no support for this hypothesis. Implied bailout probabilities of banks provided by rating agencies are unaffected by the EBA capital exercise. Instead, our empirical analysis shows that the decline in market capitalization is most consistent with reduced profitability of EBA banks following the treatment. We tie this finding to banks' response to the capital exercise, i.e., reducing risk-weighted assets.

We perform several robustness tests to ensure that other confounding factors do not drive our findings. One worry is that EBA banks are systematically different from non-EBA banks in terms of the outcomes we consider. While we show - by employing a dynamic difference-in-differences approach - that this is not the case before the capital exercise, we provide additional corroborative evidence in the following two ways. First, we focus on a subset of treatment and control banks that are more similar in terms of size. Second, we compare the evolution of risk-metrics *within* EBA banks but across different capital ratio levels before the exercise. Our results remain qualitatively robust to these alternative approaches. A second worry is that EBA banks and non-EBA banks were hit by differential shocks during the capital exercise period which lead to a different evolution in the risk-metrics we consider. A primary concern for this is the differential exposure to the contemporaneous European sovereign debt crisis. We address this concern in two ways. First, we include country $\times$ year-quarter fixed effects, effectively ensuring that identification comes from comparing different types of banks within the same country within a given year-quarter. Second, we conduct a placebo test where we compare the evolution of the non-regulatory risk measures at the onset of the sovereign debt crisis and show that the treated banks did not experience a similar increase in risk metrics then.[2]

Our paper relates to the broad literature on banks' response to higher capital requirements, see for instance Aiyar et al. (2014a,b, 2016), Kisin and Manela (2016), Fraisse et al. (2017), Jiménez et al. (2017), Célérier et al. (2018), and Juelsrud and Wold (2020). Our identification strategy is similar to Mésonnier and Monks (2015), Degryse et al. (2018) and Gropp et al. (2019), who rely on the EBA capital exercise for pinning down the causal effect of higher capital requirements on bank balance sheet items.[3] A related strand of the literature has employed bank stress tests to study the effects of changes in regulatory bank capital.[4] For example, Acharya et al. (2018) find that stress-tested U.S. banks reduce credit supply to decrease their credit risk. Similar findings are due to Berrospide and Edge (2019) and Cortés et al. (2020) who show that the stress-test induced increases in capital requirements cause affected banks to reduce small business and C&I lending, respectively.

In tandem with the literature on banks' responses to regulation, a literature on the evolution of bank solvency has emerged. Sarin and Summers (2016) highlight that market-based measures of bank risk have surged following the financial crisis. Consistent with this, Chousakos and Gorton (2017) and Bogdanova et al. (2018) document that banks' Tobin's Q has remained low after the financial crisis and discuss the underlying explanation. Gao et al. (2018) estimate the response of stock prices and bond yields for large financial institutions in the U.S. after critical events in the passage of the Dodd-Frank Act. They document that, on average, large financial institutions had negative abnormal stock returns and positive abnormal bond returns relative to small and medium-sized financial institutions in response to critical events. They interpret these findings as the Dodd-Frank Act being effective in reducing large financial institutions' risk-taking. Similarly,

[2]Due to potentially confounding events after the EBA capital exercise, such as additional regulation on large, complex financial institutions, we focus on the evolution of risk-metrics primarily during the EBA capital exercise. Our robustness tests help us to validate our identifying assumption during and shortly after the capital exercise.

[3]In a related study, Bouwman et al. (2018) employ the Dodd-Frank Wall Street Reform and Consumer Protection Act to identify the causal effects of regulation on banks in the U.S. (see also D'Acunto and Rossi, forthcoming, for an analysis of the regressive redistribution of mortgage originations due to financial regulation after 2011).

[4]For a discussion of the potential inefficiencies of stress tests based on static *risk-weighted assets* instead of dynamic *market-based* risk measures, cf. Acharya et al. (2014).

Schäfer et al. (2016) conclude that post-crisis reforms have reduced both bailout expectations and equity returns for U.S. and European financial institutions. Our paper belongs at the intersection of these two strands of the literature, by focusing on how capital requirements affect measures of risk.

Nistor Mutu and Ongena (2018) analyze the impact of several different policy measures on banks' contribution and exposure to systemic risk. Specifically, they investigate the effects of recapitalizations, guarantees, and liquidity injections on systemic risk measures and how the effects depend on banks' risk profiles. Two of their findings are that recapitalization reduces the systemic risk in the short-run, while liquidity injections - especially at longer horizons - tend to elevate systemic risk. Berger et al. (2020), on the other hand, investigate the evolution of systemic risk for U.S. banks that participated in the Troubled Asset Relief Program (TARP). They find that banks that participated in the TARP program had lower systemic risk post-intervention and that larger and ex-ante safer banks drive this. Gehrig and Iannino (2018) compute and describe the evolution of two systemic risk measures following the introduction of the Basel accord. They show that measures of systemic risk did not experience a secular decline over the period for which the various versions of the Basel accord has been implemented.[5]

Our main contribution to this literature is that we are, as far as we know, the first paper to identify the causal effect of higher capital requirements on non-regulatory measures of bank risk and investigate the mechanisms through which banks' adjustment to higher capital requirements can fail to decrease and even *increase* non-regulatory risk measures. Consistent with the descriptive evidence in Sarin and Summers (2016) and Gehrig and Iannino (2018), we show that higher capital requirements have unambiguous effects on bank risk and can even trigger an *increase* in some bank risk measures. In terms of understanding the mechanism, we show support of the main conjecture of Sarin and Summers (2016), namely that a decline in market capitalization drives the increase in risk. Moreover, we show evidence that a reduction in bank profitability drives this decline in market capitalization. Given that a reduction in risk is the key objective for policymakers considering higher

[5]Note that market-based measures of systemic risk, some of which we use in our study as well, have been criticized for not adequately capturing the actual systemic risk, but are just proxies of various aspects related to systemic issues. For example, Zhang et al. (2015) and Löffler and Raupach (2018) provide a critical perspective on these measures and their predictive power for crises. We do not take a stance on whether these measures are accurate proxies of overall systemic risk in the financial sector, but use and interpret them directly as combinations of other non-regulatory measures we employ.

capital requirements, our findings have important implications for policy. Specifically, they suggest that the overall effectiveness of higher capital requirements is much less clear than what is the case when only considering regulatory risk measures.[6] In Section VI, we discuss different strategies for improving bank solvency in light of our findings.

II. EBA Capital Exercise

The EBA announced its (first) capital exercise on October 26, 2011, following the release of stress test results on July 15. The objective of the EBA capital exercise was to restore the public's confidence in the safety of large European banks by increasing banks' capital base to a level at which banks' could withstand unexpected losses (primarily stemming from sovereign bonds). As its central provision, the capital exercise required a set of 61 European banks to increase their minimum Core Tier 1 capital from 5% to 9% by June 2012.[7]

In line with the exercise's purpose of strengthening large banks' capital buffers, inclusion in the EBA capital exercise was based on the banks' total assets. To be precise, for each country, banks were first ranked based on their consolidated assets as of the end of 2010. Banks with total assets above a *country-specific* (rather than a common EU-wide) threshold participated in the capital exercise. This asset threshold was set so that the increase in the capital requirement affected at least 50% of a national banking sector. Due to regional variation in the structure of national banking sectors, this threshold rule implied a relatively large variation in the number of banks that were affected by the increased capital requirements. Countries with banking sectors consisting of a few large banks would have few banks subject to the new requirement, whereas countries with many smaller and homogeneous banks in terms of asset size would have many banks subject to the new requirement.

To meet the new capital requirements, the EBA recommended the selected banks to use "retained earnings, reduced bonus payments, new issuances of common equity and suitably strong contingent capital, and other liability management measures" rather than reduce risk-weighted

[6] As noted by Bahaj and Malherbe (2020), the effects of capital requirements on *lending* are also ambiguous with higher capital requirements on the one hand increasing the bank's weighted average cost of funds and on the other hand alleviating the "guarantee overhang problem" thus making lending more attractive.

[7] Even though the exercise was only a recommendation by the EBA, national supervisors were nevertheless required under EU law to make every effort to comply with this recommendation.

assets.

III. Empirical Methodology

In this section, we describe how we use the EBA capital exercise in order to pin down the effect of higher capital requirements on risk metrics (in subsection III.A). We then describe the various risk metrics we consider (subsection III.B). We close this section off by discussing sample selection and providing summary statistics (subsection III.C).

A. Identification

Our identification strategy is to compare outcomes between EBA banks and non-EBA banks. As a baseline, we run a flexible difference-in-differences (see Mora and Reggio, 2012) of the form

$$Y_{i,t} = \alpha_i + \sum_{k \neq 2011\text{q}2} \beta_k \mathbf{1}_{t=k} + \sum_{k \neq 2011\text{q}2} \gamma_k \left(\mathbf{1}_{t=k} \times EBA_i\right) + \epsilon_{i,t} \tag{1}$$

where i indexes bank and t indexes time. $Y_{i,t}$ are different regulatory and non-regulatory risk-measures, outlined in section III.B. $\mathbf{1}_{t=k}$ represents year-quarter dummies and EBA_i is an indicator for whether bank i is an EBA bank or not. To control for time-invariant unobservable bank characteristics, we employ bank fixed-effects α_i. To account for potential correlation of $\epsilon_{i,t}$ across units, we cluster the estimated standard errors at the country-level.

The identifying assumption we make is that absent the EBA capital exercise, EBA and non-EBA banks would have similar outcomes of $Y_{i,t}$ conditional on the bank and time fixed effects. Conditional on this assumption being satisfied, this methodology allows us to map out the dynamic treatment effects of higher capital requirements. Specifically, γ_k's during the treatment period can be interpreted as the dynamic effect of increased capital requirements on $Y_{i,t}$.

There are at least two threats to our identifying assumption. The first threat to identification is that EBA and non-EBA banks have a different evolution in terms of the outcomes we consider for more structural reasons. Given the difference between EBA banks and non-EBA banks based on observables such as size and market capitalization that we document in section III.C, this could be a cause for concern. An advantage of using the specification in equation (1) is that, relative to a static difference in difference or a matching estimator, we can explicitly test for this. We do this by formally testing for whether γ_k is zero for k prior to the EBA capital exercise. If we cannot reject the null hypothesis on γ_k for this sub-period, we take this as supporting evidence for our identifying assumption.

In addition, we perform three additional analyses based on a more similar subsample of banks.[8] In the first subsample analysis (see Online Appendix for details), we restrict attention to only EBA banks. Our treatment indicator in this setting is the initial Core Tier 1 ratio of the EBA banks at the end of 2010. The underlying idea behind this identification approach is that EBA banks with a lower initial capital ratio are more affected by the capital exercise, compared to other banks. In the second subsample analysis, we restrict attention - wherever possible - to only consider the six banks closest to the threshold for each country. That is, we take the three largest non-treated banks and the three smallest treated banks in our sample for a given country and compare the evolution of the outcomes considered across these two groups. Finally, we follow Gropp et al. (2019) and adopt a matching approach (see Online Appendix), where EBA banks are matched with non-EBA banks based on three alternative matching strategies.

The second threat to identification is that - even if EBA and non-EBA banks are comparable before the capital exercise - they are hit by different shocks during the EBA capital exercise which in turn affect the outcomes considered differentially. A key concern is that EBA banks could be more exposed to the sovereign debt crisis or other regulatory proposals[9], and that the divergence in outcomes across EBA and non-EBA banks are driven by this. We address this concern in two ways. First, in the Online Appendix, we saturate our specification with country $\times$ year-quarter fixed effects. This effectively ensures that we compare banks within a given country in a given year-quarter. If exposure to the sovereign debt crisis is fixed at the country $\times$ year-quarter level, this approach ensures that the estimated relative difference is not driven by the sovereign debt crisis. Second, we conduct a placebo exercise (see Online Appendix) where we consider the difference in

[8] We thank an anonymous referee for suggesting these robustness tests.

[9] In October 2012, the Liikanen (2012) report recommended a structural reform to "reduce complexity, interconnectedness, and size of large and complex banking groups", which would likely target a similar set of banks as our EBA bank sample. For example, this would entail a separation of trading and deposit-taking activities or the use of bail-in instruments. Such recommendations were taken up only in January 2014 by the European commission proposal COM/2014/043 and therefore lie outside of our sample range. Krahnen et al. (2017) provide an overview of these proposals as well as U.S. equivalents. Due to these regulatory changes, we are careful in terms of interpreting differences or non-differences between EBA and non-EBA banks well after the capital exercise as being solely due to higher capital requirements.

outcomes for EBA and non-EBA banks at the onset of the sovereign debt crisis.

Reassuringly, our main results are qualitatively robust to these alternative approaches.

B. Risk Measures

In our empirical analysis, we employ a battery of different measures of bank risk. While the regulatory measure - the Core Tier 1 ratio - is relatively standard, we here briefly explain the set of non-regulatory measures of risk. Many of these measures are based on equity prices and may therefore be represented as a function of bank stock returns or prices. Some risk proxies are purely *market-based* (volatility, beta, Value-at-Risk) and others are *mixed* measures (market leverage, z-score, MES, ΔCOVAR, SRISK) using both market and book data. Each measure is likely to be an imperfect proxy for financial risk, however, looking at a broader suite of measures enables an assessment of how market participants evaluate bank solvency.

VOLATILITY We calculate stock price volatility as the standard deviation of daily stock returns in a given quarter (estimated on the basis of a rolling window of 100 days and averaged over each quarter). Generally, the default risk of a bank could be associated with volatility, as the likelihood that a bank's equity values falls below or close to zero depends on its volatility. All else equal, we therefore expect stock price volatility to decrease after a tightening of capital requirements if banks are deemed safer due to more capital buffers. For example, under the assumption of risk-free bank debt, increases in capital reduce overall book leverage and, given a stable asset value, should therefore result in a lower risk to shareholders (cf. Sarin and Summers, 2016).

MARKET_LEVERAGE Market leverage is the ratio of total assets (TA) minus book equity (EQ) plus market capitalization (MCAP) divided by the market capitalization of the bank: $\text{MARKET\_LEVERAGE} = \frac{\text{TA-EQ+MCAP}}{\text{MCAP}}$. We average daily market capitalization over a given quarter and use reported quarterly values of total assets and book equity to compute MARKET_LEVERAGE. If bank equity market values remain constant, MARKET_LEVERAGE will likely decrease following the introduction of stricter capital requirements, either because banks increase their equity proportion directly, or by shrinking overall assets (the latter option is supported by the evidence from Gropp et al. (2019) and the results in subsection IV.A). However, if the market value of equity is declining, this can potentially dampen the effect on MARKET_LEVERAGE or even increase it.

BETA Systematic risk β_{EQ} is the sensitivity of bank equity to market movements, calculated as the covariance of a bank's stock returns and market returns divided by the variance of market returns. Daily betas are computed using a rolling window of 100 trading days and are averaged for a given quarter. The market of interest is the European banking sector and thus, we use the *Datastream European Bank Index* as our measure of market returns. The equity beta is often referred to as "levered beta" as it is related to market leverage and a bank's asset risk in the following way (assuming debt is risk-free; cf. Baker and Wurgler (2015)): $\beta_{EQ} = \beta_A \frac{\text{TA-EQ+MCAP}}{EQ} = \beta_A \cdot \text{MARKET\_LEVERAGE}$, where β_A is the unlevered asset beta. Hence, both changes in β_A and changes in MARKET_LEVERAGE will affect the systematic risk of a bank.

VALUE_AT_RISK We measure equity tail risk using the Value-at-Risk (VaR) at level $\alpha = 0.05$, defined as the 5th percentile of daily stock returns. We compute VaR using the historical method based on a 100 day rolling window and take the average of daily values in a given quarter. The estimated $VaR_{5\%}$ is interpreted as the equity loss that is not exceeded with a $1 - \alpha = 95\%$ confidence level. While VaR is a measure of tail risk, it is related to the overall distribution of returns and therefore changes when the distribution shifts. As an example, when the underlying return distribution is normal with mean μ and variance σ^2, the VaR measure can be expressed as $VaR_\alpha = \mu + \sigma z_\alpha$, where z_α is the α-quantile of the standard normal distribution (similar relations hold true for, e.g., the Student t-distribution). If either the mean μ or the variance σ^2 of the return distribution shift as a result of the capital exercise, we expect to see respective changes in VaR values.

INVERSE_Z_SCORE As a measure of default risk, we employ a bank's (log) inverse z-score. The z-score is defined as the ratio of return on assets (RoA) plus the equity ratio (MCAP/TA) over the standard deviation of RoA (based on previous four quarter windows): $\text{z-score} = \frac{\text{RoA + MCAP/TA}}{\sigma_{4Q}(\text{RoA})}$. Such measure is sensitive to changes in a bank's capital structure, via market equity and overall asset growth or decline, as well as profitability and the variability of profits of the bank.[10] In essence, it describes how many standard deviations of profitability can be absorbed by the (market) equity and current profits and thus, how far a bank is from default. For interpretation, we invert the z-score such that an increase implies higher default risk and take its log.

Finally, we use three measures that are often considered by the literature as proxies for various aspects of systemic risk: (1) Marginal Expected Shortfall (MES) (Acharya et al., 2017), (2) SRISK (Acharya et al., 2012), and (3) ΔCOVAR (Adrian and Brunnermeier, 2016). Further details on the three systemic risk measures are given in the Online Appendix. Below, we summarize their definition and how they are estimated.

MES As a measure of a bank's systemic risk exposure we consider MES (see Acharya et al., 2017; Brownlees and Engle, 2017), which is defined as the return on a bank's equity during tail events of the financial sector.[11] To proxy for the European financial sector, we use the *Datastream European Bank Index*. We follow the estimation model of Brownlees and Engle (2017) and employ the dynamic "long-run"-MES as a proxy for a bank's exposure to such systemic tail events. Daily MES estimates are computed using TARCH and Dynamic Conditional Correlation (DCC) specifications (see Rabemananjara and Zakoïan, 1993; Engle, 2002) and are aggregated to the quarterly level by averaging. Intuitively, MES can be viewed as a sensitivity to tail events in the banking sector. In fact, as shown by Benoit et al. (2014), MES can be expressed as the product of a bank's equity beta and the expected shortfall of equity returns. Therefore, shifts in systematic risk or tail risk following the capital exercise will ultimately influence MES. In our regressions, we ultimately use the long-run MES (LRMES), which is proportional to MES. Specifically, $\text{LRMES}_{i,t} \equiv 1 - \exp(-18 \times \text{MES})$. LRMES is a measure of how sensitive the bank equity return is to a prolonged decline in market returns.

ΔCOVAR We measure a bank's contribution to systemic risk by looking at a bank's ΔCOVAR (see Adrian and Brunnermeier (2016)). The conditional ΔCOVAR measures changes in the financial

[10]Note that we employ the market value of equity to calculate the equity ratio for z-score as we are interested in the market-based component of the equity risk. However, taking the book equity is also possible and we use the book-based version in unreported analyses. Since we do not find that EBA banks necessarily adjust their book values of equity, the inverse z-score would only pick up changes in total assets, profitability, and its variability.

[11]Acharya et al. (2017) introduce the Systemic Expected Shortfall (SES), which consists of a linear combination of MES and market leverage, which we consider above.

system's Value-at-Risk in case an individual bank's VaR shifts from its median state to the extreme left tail (i.e., when the bank is in distress). As we focus on the European banking market, we do not use the state variables based on U.S.-level data as proposed by Adrian and Brunnermeier (2016) to estimate ΔCOVAR. Instead, we consider appropriate European state variables, i.e., the change in the Euro yield curve, the change between the ten-year Euro area yield rate and the three-month Euro interest rate, the Euro Stoxx 50 return, real estate returns in excess of the Euro Stoxx 50 equity market, the short-term Treasury Bill Eurodollar spread and the change in the credit spread VSTOXX.

SRISK Our final measure related to systemic risk is the estimated *conditional capital shortfall*. The capital shortfall $\mathrm{CS}_{i,t}$ of an institution i at time t is defined as

$$\mathrm{CS}_{i,t} \equiv \kappa \left(D_{i,t} + \mathrm{MCAP}_{i,t} \right) - \mathrm{MCAP}_{i,t} \tag{2}$$

where $D_{i,t}$ is book debt and $\mathrm{MCAP}_{i,t}$ is the market-value of equity. The parameter κ is meant to parametrize a prudential level of capital.[12] A positive value of $\mathrm{CS}_{i,t}$ indicates that the institution has a positive capital shortfall, whereas an institution with a negative $\mathrm{CS}_{i,t}$ is considered adequately capitalized. The estimated *conditional capital shortfall* - or SRISK - of an institution is given by

$$\mathrm{SRISK}_{i,t} \equiv \kappa \times D_{i,t} - (1-\kappa) \times (1 - \mathrm{LRMES}_{i,t}) \times \mathrm{MCAP}_{i,t} \tag{3}$$

SRISK therefore captures, intuitively, how undercapitalized an institution is expected to be conditional on a general (financial) market downturn. We calculate an institution's SRISK by combining quarterly balance-sheet and market information on $D_{i,t}$ and $\mathrm{MCAP}_{i,t}$, together with our own estimates of LRMES. SRISK captures an institution's systemic relevance by providing an actual estimate of the capital shortfall in a crisis.

[12] The parameter essentially captures when an institution is "short on capital" relative to their target market leverage ratio. We follow Bostandzic and Weiß (2018) and compute bank-specific κ's based on each institution's derivative assets and liabilities. Specifically, we compute the bank's gross derivative usage, and, on a yearly basis, divide banks into six equal groups based on the extent to which banks use derivative positions. We set $\kappa = 5.5\%$ for banks with a high level of derivatives and $\kappa = 8\%$ for banks with a low level of gross derivatives.

C. Data Sample

Our initial sample consists of all publicly traded European banks included in the active and dead firm list in *Thomson Reuters Financial Datastream.* We consider a bank's country to be the country of its primary listing and only consider countries that have at least one bank designated as a 'EBA bank'. All secondary listings and non-primary issues are excluded. This initial sample comprises a total of 115 banks. Quarterly financial accounting data are taken from the *SNL Financial* database and whenever quarterly data are missing, we cross-check and complement with data from *Capital IQ*. Daily data on share prices, earnings per share, and number of shares are retrieved from *Thomson Reuters Financial Datastream.* Due to the fact that *Datastream* suffers from well-known minor data errors with regard to stock prices, we perform several screening-procedures as proposed by Ince and Porter (2006) on the daily returns on banks' stock prices. First, a minimum share price of EUR 1 is required for a bank to be included in our sample. Second, any return above 300 percent that is reversed within one month is treated as missing. Also, we exclude a bank if the number of zero return days is more than 80 percent in a given month of that year (see, e.g., Hou et al. (2011)). Non-trading days are excluded from our sample, if 90 percent or more of the stocks listed on a given exchange have a return equal to zero. Most of the bank stocks excluded this way have stock prices below EUR 1 (19 in total); and others suffer from stale prices, i.e., *Datastream* reports them as active stocks although they are inactive during the relevant time period (4 banks). Overall, these filters reduce our sample to 92 banks. Finally, we follow Gropp et al. (2019) and exclude seven banks from our sample that undergo "deep restructuring" or were acquired during the sample period.[13] In summary, due to our filters, the initial list of 115 bank stocks is reduced to our final sample of 85 banks, which consists of 29 EBA banks (treatment group) and 56 non-EBA banks (control group).[14] Our sample runs from Q1:2010 to Q4:2013, but we collect market data starting from 2009 (if available) in order to estimate some of the risk measures on a rolling basis. To ensure the comparability within our sample of European banks, all stock market and accounting data are collected in Euro.

[13] There are six Greek EBA banks (Attica Bank, Eurobank Ergasis, Bank of Piraeus, Alpha Bank, Bank of Greece, National Bank of Greece) as well as one Belgian bank (Dexia), which were acquired by the state.

[14] The sample filters applied in Schmidt (2019) are similar to ours and comprise 31 EBA banks and 58 non-EBA banks that have available data on analyst forecasts. In the Online Appendix, we show results from an analysis using the full initial sample. The results are largely similar to the results shown for our main sample.

Summary statistics for our main variables of interest as of Q4:2010 (cf. Gropp et al., 2019) are presented in Table 1. The average CT1 capital ratio (CT1_RATIO) of EBA banks is 9.9%, while non-EBA banks, on average, exhibit an almost 2 percentage point higher ratio in Q4:2010. The mean CT1_RATIO for EBA banks is above the 9% level prescribed after the EBA capital exercise, but there are number of banks that fall below the prescribed threshold prior to 2011. While the treatment group is not assigned via total but the relative size of the bank in its country, we observe that the average EBA bank has total assets of over EUR 600 billion versus ca. EUR 16 billion for the average non-EBA bank. Thus, we also find that the overall capital shortfall is much higher for EBA banks. For example, the maximum SRISK in the treatment group is around EUR 87 billion while the highest value for the control group is only around EUR 9 billion. Similarly, systemic risk *contribution*, measured via ΔCOVAR, is three times higher for the average EBA bank and the mean of the long-run *MES* is twice as high.

Market capitalization is magnitudes higher for EBA banks compared to banks in the control group and thus, given the smaller amount of total assets, market leverage is twice as high for non-EBA banks. Finally, EBA banks exhibit higher default risk, tail risk, and systematic risk, hold less book equity, and are less profitable prior to the capital exercise in 2011. While there are differences between EBA and non-EBA banks in terms of size and risk prior to the treatment, we emphasize that our econometric setup does not assume similarity based on these pre-treatment characteristics. Rather, our identifying assumption is a similar *evolution* of the various outcomes we consider in absence of treatment.

IV. Capital Requirements and Bank Risk

In this section, we explore how capital requirements affect bank risk. We start this section by documenting how EBA banks respond to the capital exercise in terms of (1) equity, (2) the risk density of its assets[15], and (3) total assets, and how the adjustment of these variables ultimately affect banks' Core Tier 1 ratio. The overall conclusion from section IV.A is that Core Tier 1 ratios increase. We then move on to investigate whether we observe a similar development in other risk metrics (section IV.B). We document how non-regulatory market-based risk-metrics remain

[15] We define the risk density of assets as risk-weighted assets divided by total assets.

Variable	Sample	N	Mean	SD	Min	Max
CT1_RATIO	EBA	25	9.94	2.31	4.00	13.94
(in %)	Non-EBA	46	11.78	3.90	5.96	21.38
MCAP	EBA	28	42,644	66,829	1,420	290,297
(in million EUR)	Non-EBA	56	2,579	7,682	5	45,229
MARKET_LEVERAGE	EBA	27	21.41	14.82	2.98	59.43
	Non-EBA	46	46.47	70.11	1.63	338.41
VOLATILITY	EBA	29	1.72	0.48	0.23	2.63
(in %)	Non-EBA	56	1.99	0.65	1.06	5.09
BETA	EBA	29	0.83	0.22	0.42	1.30
	Non-EBA	56	0.25	0.26	-0.23	1.04
VALUE_AT_RISK$_{5\%}$	EBA	29	-3.49	1.92	-12.95	-2.15
(in %)	Non-EBA	56	-2.87	1.35	-9.06	-0.41
INVERSE_Z_SCORE	EBA	26	1.17	3.56	0.06	18.50
	Non-EBA	45	0.46	2.82	-12.79	10.05
LRMES	EBA	29	58.83	11.62	37.50	93.10
(in %)	Non-EBA	56	32.11	21.56	-15.48	78.78
ΔCOVAR	EBA	29	-0.47	0.72	-2.27	0.94
(in %)	Non-EBA	56	-0.15	0.25	-1.27	0.33
SRISK	EBA	27	19,942	30,248	-26,175	87,430
(in million EUR)	Non-EBA	46	-48	2,965	-14,912	8,998
TOTAL_ASSETS	EBA	27	625,901	659,609	20,248	1,998,158
(in million EUR)	Non-EBA	46	16,540	34,245	137	214,684
EQUITY_RATIO	EBA	27	6.44	2.86	2.64	13.38
(in %)	Non-EBA	46	9.27	3.89	2.62	17.63
ROA	EBA	26	0.12	0.11	-0.02	0.49
(in %)	Non-EBA	47	0.19	0.17	-0.20	0.73

Table 1: Summary Statistics (Q4:2010)

This table shows summary statistics of regulatory and non-regulatory risk measures, total assets, return on assets, and equity ratios for a sample of 29 treated EBA banks and the control group of 56 non-EBA banks.

unchanged or even spike after the introduction of stricter capital requirements.

A. How Do Banks Respond to Increased Capital Requirements?

Our point of departure is a similar analysis as conducted by Gropp et al. (2019), who document how EBA banks responded to the EBA capital exercise. We start by showing how the capital ratio of EBA banks changed as a result of the capital exercise. That is, we use the CT1 ratio as outcome variable in equation (1). The sequence of estimated $\{\gamma_k\}$ from equation (1) is shown in Figure 1.

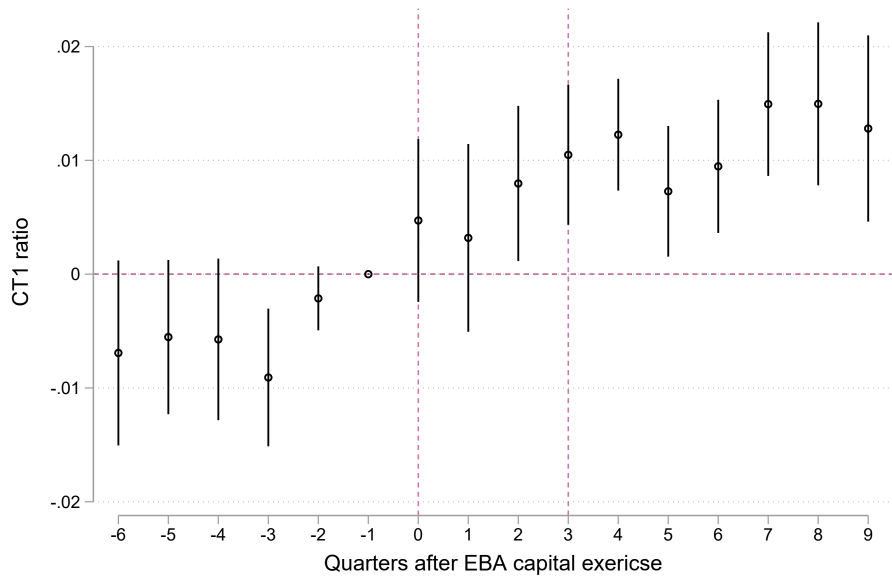

Figure 1: This figure shows the evolution of the average Core Tier 1 (CT1) ratio of EBA banks relative to non-EBA banks. Specifically, we plot the sequence of estimated $\{\gamma_k\}$ from equation (1). Vertical bars correspond to 95% confidence intervals. Standard errors are clustered at the country level.

The picture is clear and consistent with Gropp et al. (2019). EBA banks significantly increase their CT1 capital ratios at the onset of the capital exercise. On average, capital ratios had increased by roughly 1.5 percentage points nine quarters after the EBA capital exercise, leaving EBA banks significantly better capitalized compared to what they were before.

Next, we investigate how banks achieved this increase in capital ratios. In principle, banks can adjust in three ways: (1) increasing equity, (2) decreasing assets, or (3) changing the composition of assets such that the average risk-weight is lowered (i.e., "portfolio rebalancing"). Our outcome variables are therefore the level of total (log) assets, the level of (log) equity, and the risk density, captured by risk-weighted assets divided by total assets. The results are shown in Figure 2.

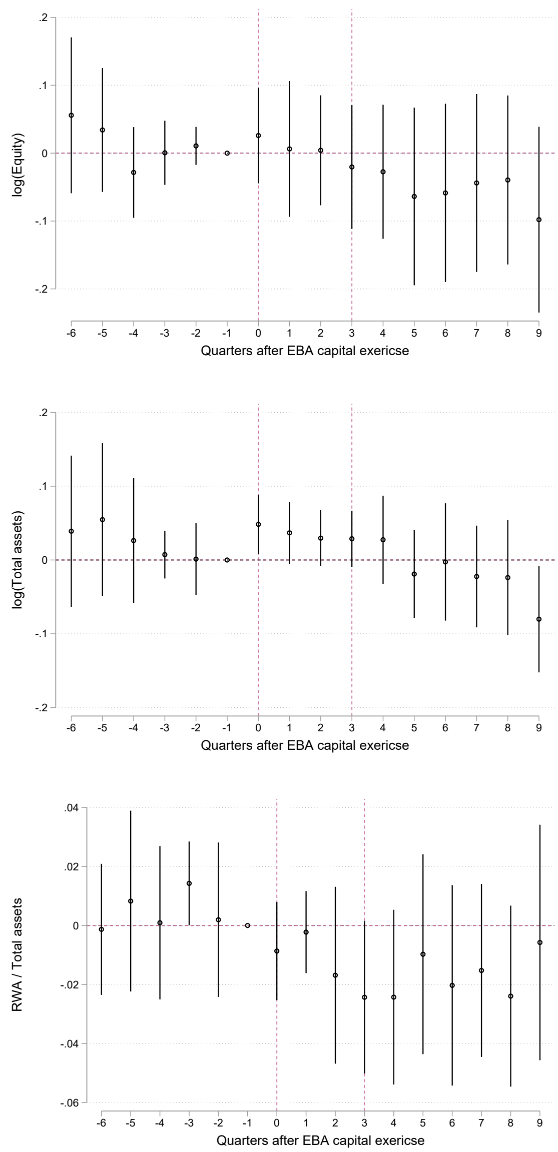

Figure 2: This figure shows the evolution of log(equity) (top row), log(assets) (mid row), and risk-weighted assets divided by total assets (bottom row). We plot the sequence of estimated $\{\gamma_k\}$ from equation (1). Vertical bars correspond to 95% confidence intervals. Standard errors are clustered at the country level.

Our results are broadly consistent with the findings of Gropp et al. (2019), despite stemming from a slightly different sample. EBA banks reduce risk-weighted assets, while equity has a roughly similar evolution across treatment and control banks in the short-term. The reduction in risk-weighted assets is achieved by both a reduction in total assets over the longer-term (mid row), but mainly a reduction in the overall risk density (bottom row). The latter indicates that not only do capital requirements affect the overall level of credit, but also the allocation.

A tentative conclusion based on this section is that higher capital requirements decreases the risk-density of banks and increase banks' CT1 ratio. Taken together, this suggests unambiguously that bank solvency improves. According to standard financial theory, this should then also improve other, market-based measures of risk. For instance, higher capital ratios should, all else equal, make banks' equity less responsive to movements in overall economic conditions. Reduced comovement with the business cycle should reduce the required return on bank stock. However, banks' response to higher capital requirements can dampen or even reverse these effects. For instance, if banks engage in portfolio rebalancing to assets that are more correlated with the state of the economy, that could dampen the reduction in the systematic risk of bank equity. Moreover, shifts in bank portfolios have implications for bank profitability. This seems especially relevant, given there are potential losses in banks' franchise value, a concern expressed by, e.g., Sarin and Summers (2016). Changes in bank profitability can affect the market valuation of banks, which in turn affects several risk-metrics. Therefore, we now move on to the main analysis of the paper, which consists of investigating whether we also observe a decrease within a much broader set of non-regulatory risk-metrics.

B. The Effects of Capital Requirements on Bank Risk

We start by considering three measures related to equity return risk: Value-at-Risk, systematic risk, and stock return volatility. The relative evolution of these measures for EBA banks around the period of the EBA capital exercise is shown in Figure 3.

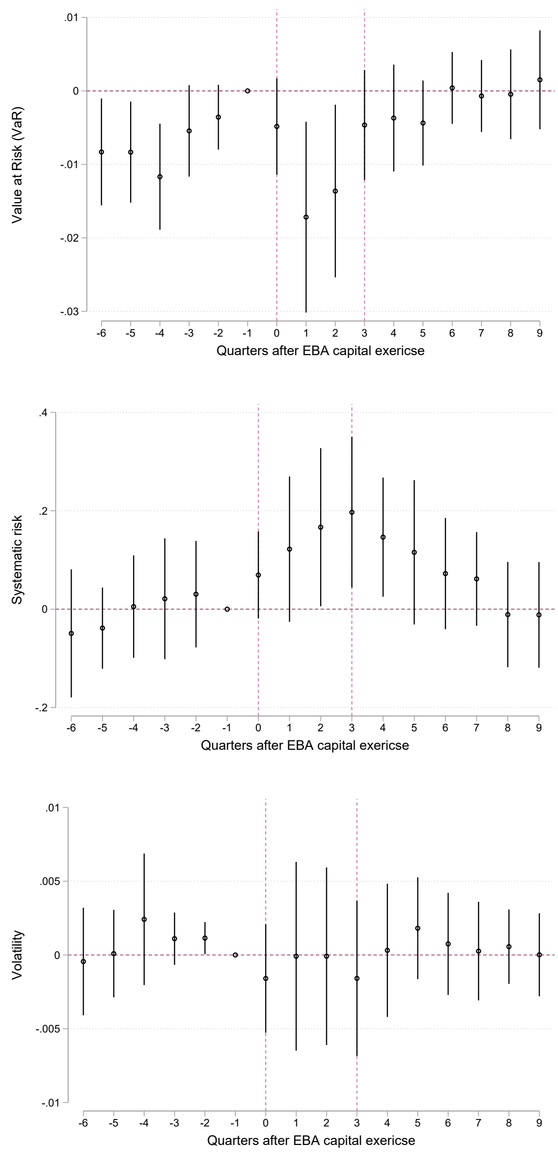

Figure 3: This figure shows the evolution of $VaR_{5\%}$, systematic risk (beta), and stock return volatility. In all panels, we plot the sequence of estimated $\{\gamma_k\}$ from equation (1). Vertical bars correspond to 95% confidence intervals. Standard errors are clustered at the country level.

Starting with the top row, there is a relative decline in Value-at-Risk for the treatment group of EBA banks, which corresponds to increasing equity tail risk, i.e., the 5th percentile of equity returns declines temporarily. In the quarters immediately after the capital exercise, absolute values of VaR are up to 1-2% higher for banks that had to increase their CT1 capital ratios. In the mid row, we observe the relative evolution of systematic risk β_{EQ}, which also shows a relative increase at the onset of the EBA capital exercise. Both measures, VaR and β_{EQ}, exhibit elevated risk for EBA banks for over six and eight quarters, respectively, but then revert back to similar levels as for non-EBA banks in the longer-term. In the bottom row, we show that the relative stock-return volatility of EBA banks does neither increase nor decrease significantly. The effect of capital requirements on the idiosyncratic volatility is thus, inconclusive. An important observation, however, is that there is no significant decline in volatility despite the increase on the CT1 ratio as documented in section IV.A.

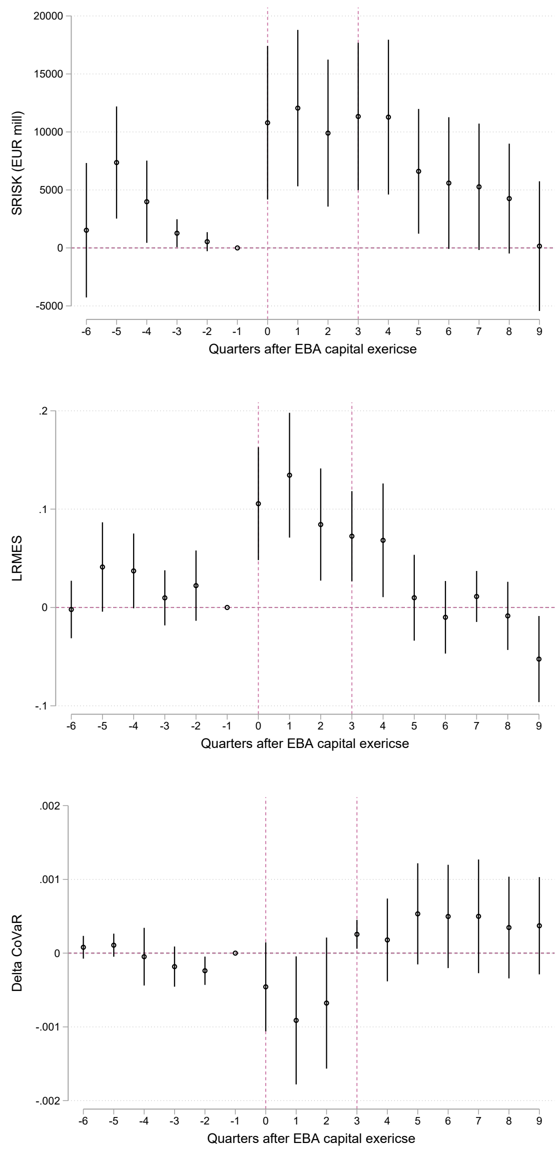

Figure 4: This figure shows the evolution of SRISK, LRMES, and ΔCOVAR. In all panels, we plot the sequence of estimated $\{\gamma_k\}$ from equation (1). Vertical bars correspond to 95% confidence intervals. Standard errors are clustered at the country level.

Next, we move to the three systemic risk measures, with estimated effects shown in Figure 4. In general, the findings for our systemic risk measures mirror the evolution of the effects on the equity-based risk measures they are composed of. LRMES is a combination of beta and equity tail risk and thus, we find the same pattern for LRMES as for its components: LRMES rises sharply for EBA banks following the capital exercise in 2011 and remains elevated for over a year until the treatment effect reverts to zero. The SRISK measure is proportional to LRMES and therefore exhibits a similar evolution over time. The effect of the capital exercise on EBA banks' ΔCOVAR is mixed. Initially, the overall risk relatively increases for the first three quarters (i.e., lower values of ΔCOVAR), but is reverted quickly. Importantly, as for equity volatility, ΔCOVAR never significantly improves.

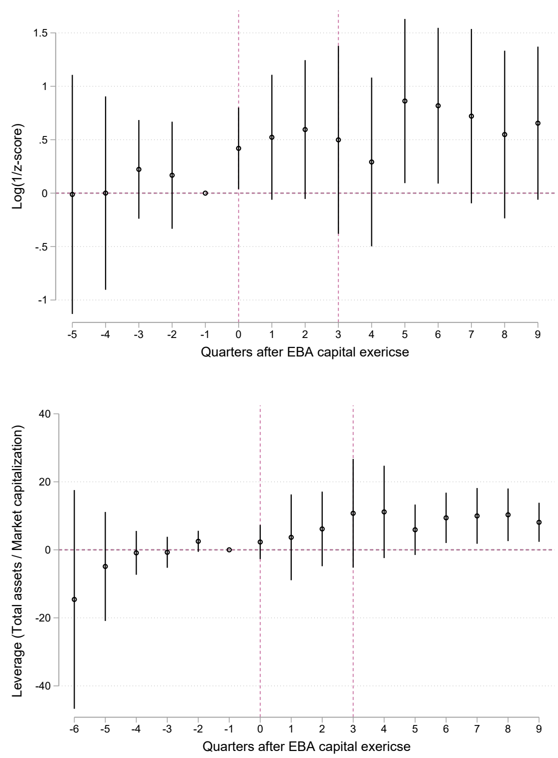

Figure 5: This figure shows the evolution of the inverse z-score and market leverage. In all panels, we plot the sequence of estimated $\{\gamma_k\}$ from equation (1). Vertical bars correspond to 95% confidence intervals. Standard errors are clustered at the country level.

Finally, in Figure 5, we show the response of our two solvency measures to the increase in capital requirements. In the top row, we show the evolution of the log of (inverse) z-score. As highlighted in section III.C, this measure is a function of (1) the return on assets (RoA), (2) the market-based equity ratio (MCAP/TA), and (3) the standard deviation of RoA. In the bottom row, we show the evolution of treatment effects for market leverage. Our estimates indicate that both the inverse z-score and market leverage of EBA banks *increase* relative to non-EBA banks.

Summary of results The preceding analyses indicate that non-regulatory, market-based risk measures are unchanged or elevated following the tightening of capital requirements, i.e., bank risk for treated banks is (weakly) higher rather than lower. In the Online Appendix, we show that this increase in relative risk is primarily driven by a larger increase in level of the various risk-metrics rather than a smaller decline, providing support for the interpretation that higher capital requirements in fact *increase* market-based measures of bank risk. These findings are consistent with the descriptive evidence in Sarin and Summers (2016), and in sharp contrast to the results in section IV.A, which indicate that higher capital requirements increase bank capital ratios and reduces banks' risk density. To the extent that these market-based measures are informative for bank insolvency risk, then, our findings reveal that the overall impact of capital requirements on bank risk is more complex compared to assessments based on regulatory capital ratios alone.

C. Robustness

To motivate our causal interpretation of the treatment effects shown in section IV.B, we perform multiple robustness tests to validate our identifying assumption. All results from the robustness tests are shown in the Online Appendix, but omitted here for brevity. Instead, we summarize the robustness exercises without showing the full set of results. Our results remain largely unchanged across the different robustness tests.

The first robustness exercise addresses the concern that our results are driven by exposure to the sovereign debt crisis in Europe. To alleviate such concern, we perform a falsification test where we compare the evolution of our risk-metrics at the onset of the sovereign debt crisis. If exposure to the sovereign debt crisis is driving our main results, we would expect to see a similar evolution of our risk metrics for this alternative sample period. We do not find such patterns. As an alternative way of addressing this concern, we also saturate our specification with country $\times$ year-quarter fixed effects, effectively ensuring that identification comes from comparing EBA with non-EBA banks within the same country and time period. The results using this alternative specification is qualitatively similar to that reported in the main text.[16]

The next two robustness tests are analyses that focus on more narrow samples.[17] For identification, this ensures to a larger extent that we compare the evolution of risk-metrics across different banks that are more similar in terms of observables. First, we restrict attention to the 29 EBA banks only. As a measure of treatment intensity, we use the inverse of the Core Tier 1 ratio at the end of 2010. The underlying idea behind this identification strategy is that banks with initial higher capital ratio were less affected by the increase in capital requirements. Reassuringly, we also find that within the EBA bank subsample, the non-regulatory risk metrics increase significantly more for less capitalized banks, compared to banks that initially had higher capital ratios. This lends support to the interpretation that the increase in risk-measures is not due to EBA status per se, but the actual increase in capital requirements. Second, we compare the three EBA banks closest to the thresholds in our sample with the three non-EBA banks just below the threshold for each country.[18] Within this sample, we find qualitatively similar results.

Due to the selection rule in the EBA capital exercise, we can also adopt a matching approach where we match EBA and non-EBA banks based on observables. In the Online Appendix, we show the estimated effect of the EBA capital exercise on our outcome variables replacing our original control group with a matched control group. We adopt three different matching strategies: size (market capitalization, SRISK and total assets), business model (deposit ratio, net interest margin, loan ratio and RoA) and capitalization (Tier 1 ratio and market leverage). Matching is done based on end-of 2010 values of the respective matching variables. We find qualitatively similar results across all matching strategies compared to the results reported in the main text.[19]

Finally, we repeat our main tests using an extended sample of banks to ensure that our estimates are not specific to our selected sample. In particular, we do not exclude banks with share prices below EUR 1 during the sample period and also keep the seven banks that experienced "deep restructuring" during the time period (see Gropp et al., 2019).[20] The results remain both

[16]The only exception is the impact of higher capital requirements on stock price volatility. According to our estimates, shown in the Online Appendix, stock price volatility declines. In our main set of results, this effect is statistically indistinguishable from zero.

[17]We thank the anonymous referee for these suggestions.

[18]Whenever a country has less than three banks just above or just below, we include all of them.

[19]We retain the matching exercise as a robustness exercise due to the small number of uniquely matched control banks for each EBA bank.

[20]Results using this broader sample are given in the Online Appendix.

qualitatively and quantitatively similar to the results in the main text.

All in all, these robustness tests lend support for our identifying assumption of similar outcomes for EBA banks and non-EBA banks in absence of the capital requirement increase during and shortly after the exercise.

V. Capital Requirements and the Market Valuation of Banks

Our findings so far indicate that market-based measures of bank solvency remain unchanged or even increase after the EBA capital exercise, despite an increase in banks' CT1 ratio and a reduction in banks' risk density. In this section, we explore why this is the case. As highlighted in section III.C, some of our risk measures are functions of (changes in) the market value of bank equity. The debate concerning how banks are affected by higher capital requirements has also primarily focused on banks' franchise values (Sarin and Summers, 2016; Gao et al., 2018; Bogdanova et al., 2018). Our focus of this section is therefore on two questions. Do higher capital requirements have an impact on banks' market capitalization and, if so, why?

A. The Impact of Higher Capital Requirements on Banks' Market Capitalization

We start by investigating whether higher capital requirements affect banks' market capitalization. Figure 6 shows the dynamic treatment effects from estimating equation (1) using (log) market capitalization as outcome variable $Y_{i,t}$.

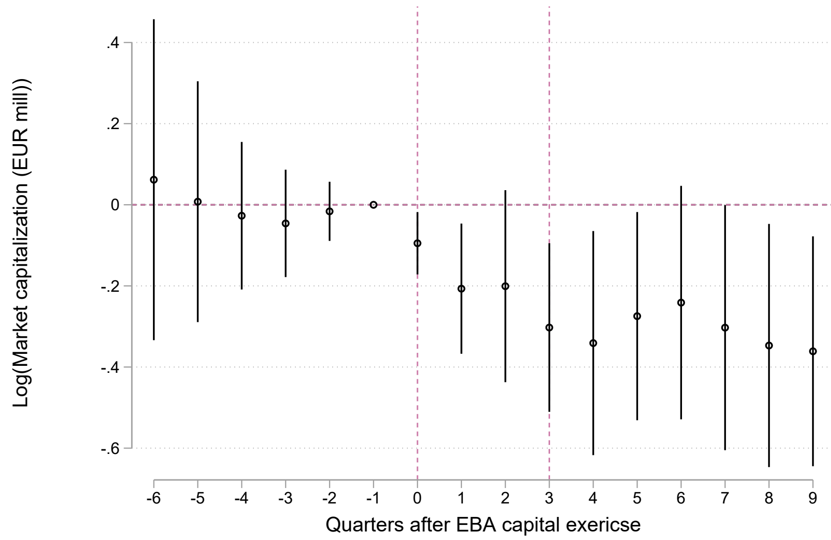

Figure 6: This figure shows the sequence of estimated $\{\gamma_k\}$ from equation (1) using the log of market capitalization as outcome variable. Vertical bars correspond to 95% confidence intervals. Standard errors are clustered at the country level.

The estimated coefficients suggest that market values of EBA banks decline significantly relative to non-EBA banks following the EBA capital exercise.

This decline in market capitalization can explain the evolution of non-regulatory risk metrics documented in section IV.B. For example, an equity market loss combined with only slight reductions in total assets, increases the market leverage and default risk (INVERSE_Z_SCORE) of banks. Consequently, the evolution of risk measures such as LRMES, SRISK, or BETA, which can in part be presented as functions of market leverage, are also affected - consistent with a permanent EBA bank equity devaluation.[21]

[21] The initial increase and subsequent reversion of the equity beta over time documented above may be explained by an initial increase in market leverage that is later reversed by a reduction in a bank's asset risk (e.g., by the cut in lending and subsequent reduction of risk-weighted assets by EBA banks in response to tighter capital requirements (see Gropp et al., 2019)). For example, if systematic risk can be expressed as $\beta_{EQ} = \beta_A \cdot \text{MARKET\_LEVERAGE}$ (see section III.B), then the increase in MARKET_LEVERAGE could have been counterbalanced in the longer-term by reducing a bank's asset risk exposure β_A. Note that this potential explanation only holds in the absence of other forces driving bank decisions in the longer-term. To allow causal inference from this single event, our identifying assumption needs to hold for the whole period of eight quarters following the capital exercise. The longer the time period after the exercise, the stronger our assumption is.

B. Channels Through Which Higher Capital Requirements Affect Market Capitalization

We now explore why higher capital requirements reduce banks' market capitalization. A devaluation of EBA banks' equity can occur for a number of reasons. In the following, we consider three potential explanations: (1) changes in any subsidy from implicit or explicit government guarantees, (2) changes in bank dividends, and (3) changes in bank profitability. Understanding which of these channels are important for the decline in EBA banks market capitalization is central in order to evaluate the welfare effects of higher capital requirements. For instance, if it arises from a reconsideration of implicit or explicit too-big-to-fail subsidies, the decline in market values and associated increase in bank risk can be good from a social planner's perspective. If, on the other hand, higher capital requirements reduce market capital and increase bank risk due to lower profitability, it leave banks less solvent without any associated positive effects.

Too-big-to-fail Subsidies To assess whether higher capital requirements reduce implicit or explicit too-big-to-fail (TBTF) subsidies for EBA banks, we follow Noss and Sowerbutts (2012) and focus on rating agencies' subjective judgment of the likelihood of government intervention. The *Fitch Solutions* database provides explicit "support ratings" for a subset of our banks. The support ratings are supposed to capture 'a potential supporter's propensity to support a bank and of its ability to support it'.[22] We have data on support ratings for a subsample of 37 banks, of which 20 are EBA banks. We focus on 2011 (starting before the capital exercise) and onwards due to data accessibility. We use our data on support ratings to assess whether they change significantly for EBA banks relative to non-EBA banks during the treatment period.[23] For the sake of interpretability, we follow Gropp et al. (2011) and assign a direct mapping from support ratings to bailout probabilities. Implied probabilities of bailouts for EBA and non-EBA banks are shown in

[22] Note that Fitch bank support ratings "do not assess the intrinsic credit quality of a bank" but rather "[...] communicate the agency's judgment on whether the bank would receive support should this become necessary." (cf. `https://info.creditriskmonitor.com/Help/FitchGlossary.asp`)

[23] Measuring implied bailout probabilities is empirically challenging. In the Online Appendix, we follow an alternative approach that captures implied bailout probabilities by computing bank-specific put option spreads (see Kelly et al., 2016) as these may indicate whether a bank stock's crash insurance carries a TBTF premium. However, option data on banks in our sample are even more scarce than ratings data (i.e., 15 EBA banks and 6 non-EBA banks) and thus, we only refer to these results as additional support for our findings. The results following that approach are largely consistent with the results presented here.

Figure 7.

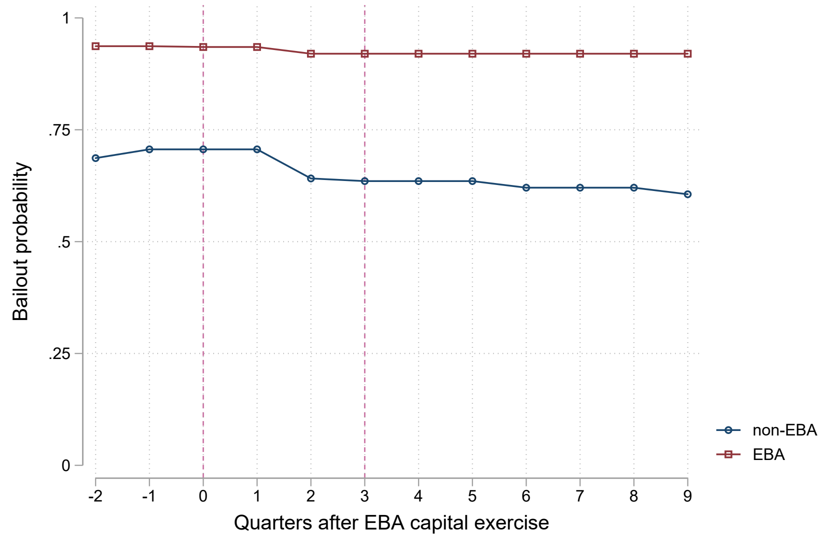

Figure 7: Bailout probabilities for a sample of 20 EBA banks and 17 non-EBA banks. The probabilities are based on Fitch's support rating of the respective banks. The support ratings are then mapped to bailout probabilities, following Gropp et al. (2011).

Figure 7 shows average bailout probabilities of EBA versus non-EBA banks. Banks in the former group tend to have a higher average bailout probability throughout the sample period. However, considering the evolution of those probabilities, there are no clear changes in the estimated bailout probabilities surrounding the EBA capital exercise.[24] If stricter capital requirements imposed lower bailout probabilities, it is likely that we would observe a more significant drop in such probability for banks affected by the exercise. To the extent that the credit rating agencies support rating and the expectations of other market participants coincide, we argue that it is unlikely that a change in the TBTF subsidy can explain the observed reduction in bank equity market values for the whole sample of treated banks.

Dividends Theoretically, the impact of dividend reductions on market valuations is ambiguous. However, a large literature starting from Bhattacharya (1979) focuses on the positive comovement between dividends and share prices. In light of this literature, a simple explanation for an immediate drop in the market value of bank equity may therefore be that EBA banks temporarily postpone dividend payouts. We note that the lack of relative increase in equity as documented in section

[24]In specific, there are only seven banks that experience a change in support ratings during our sample period.

IV.A is inconsistent with a large reduction in dividend payouts. However, due to for instance equity injections and losses, the path of equity can differ from the path of dividend payouts. Here, we therefore investigate the impact of the EBA capital exercise on dividend payouts directly.[25] To exclude changes in dividends due to changes in net income, we scale dividends by net income and focus on the dividend payout ratio.

Figure 8 shows annual dividend payout relative to a bank's net income for EBA versus non-EBA banks.

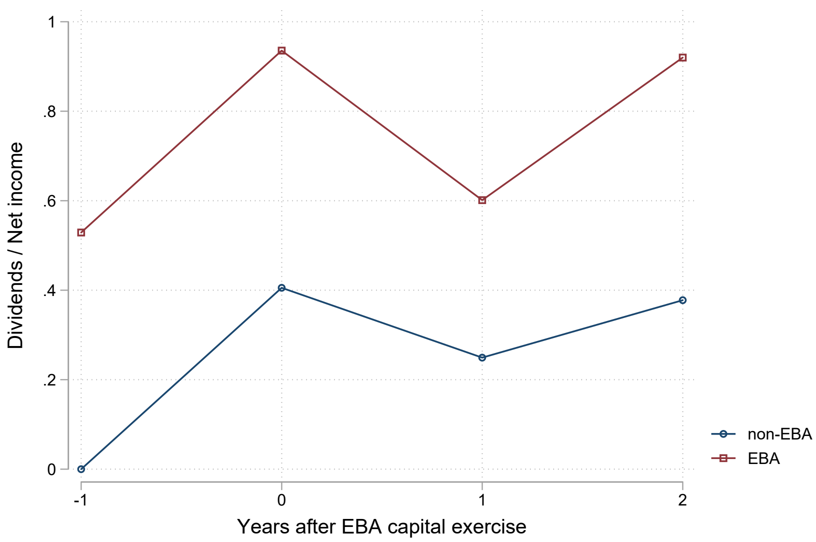

Figure 8: This figure shows the evolution of median dividends paid relative to net income for EBA and non-EBA banks.

The evolution of median dividend payouts is largely the same for treatment and control group. Dividend payouts in 2011 are slightly higher for both groups compared to the end of 2010, which is inconsistent with drops in dividend payouts driving market equity drops after the exercise. In 2012, we observe an overall decrease in median dividends payments, and EBA banks have a slightly higher drop in the dividends to net income. While this is consistent with market capitalization declining in general, it does not explain the overall differential evolution of market equity values of EBA banks versus non-EBA banks. It is therefore unlikely that it can explain the differential decline in market equity values for EBA banks.

[25] Investigating the impact of the EBA capital exercise on dividends, however, is challenging due to data limitations, as dividend payout is inherently an annual variable. Hence our sample only contains four dividend-observations per bank.

Bank profitability Finally, as the last potential explanation for why the market capitalization of EBA banks drop, we investigate how the capital exercise affects bank profitability. Given the portfolio rebalancing documented in subsection IV.A, it is plausible that higher capital requirements influence overall bank profitability as banks may have had to cut down on loans that may exhibit positive net cash flow. For that purpose, we plot the evolution of the treatment effect on RoA using our full sample of 85 banks in Figure 9.

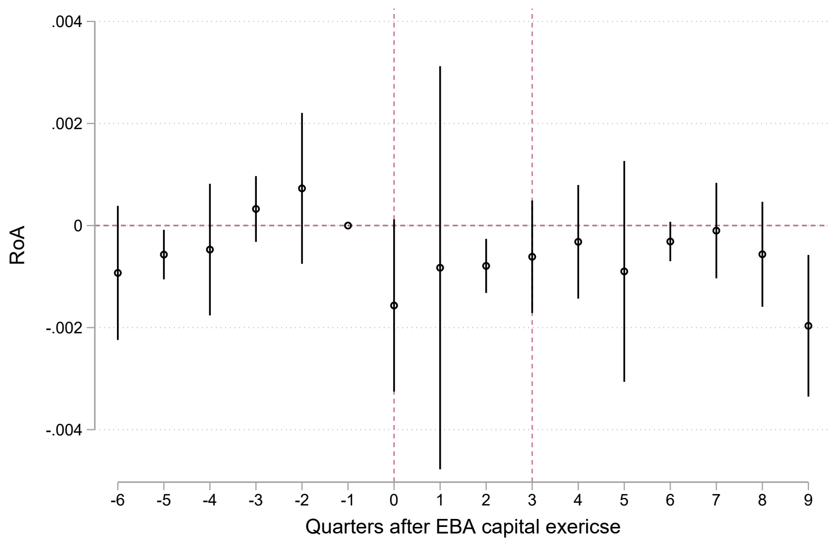

Figure 9: This figure shows the sequence of estimated $\{\gamma_k\}$ from equation (1) using Return on Assets (RoA) as outcome variable. Vertical bars correspond to 95% confidence intervals.

While the two groups may have a relatively similar trend in RoA prior to the capital exercise, there is a systematic difference between treatment and control groups at the onset of the capital exercise. EBA banks exhibit a significantly lower RoA compared to non-EBA banks and this difference persists throughout and after the capital exercise. A relative devaluation of EBA bank stocks is consistent with such relative loss in profitability for EBA banks.

Putting it all together To summarize the analysis above, we estimate the following static difference-in-differences regression:

$$Y_{i,t} = Post_t + EBA_i + \gamma \times (Post_t \times EBA_i) + \epsilon_{i,t}, \tag{4}$$

	1 Log(Market capitalization)	2 RoA	3 Dividends / Net Income	4 Bailout probability	5 Net income (thousands EUR)
$Post_t \times EBA_i$	-0.264* (0.148)	-0.000667** (0.000305)	-44.81 (50.73)	0.00218 (0.0428)	-410599.7** (156059.3)
N	1,344	1,210	1,300	510	1,333
Clusters	14	13	14	13	13
Bank FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes

Table 2: Putting It All Together: Static Difference-in-differences
This table shows the results from estimating equation (4). Standard errors in parentheses are clustered at the country level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

where γ is the coefficient of interest. γ captures the average change in the outcomes we consider for EBA banks relative to non-EBA banks over the capital exercise period. As our outcome variables $Y_{i,t}$, we consider log(market capitalization), Return on Assets, Dividends / Net Income, the implied bailout probability based on bank support ratings, and raw net income.

Consistent with Figures 6, 7, 8, and 9, there is a statistically significant relative decline both in market capitalization and RoA for EBA banks during the capital exercise. Moreover, the drop in RoA is associated with a decline in Net income (column 5). In contrast, there is no significant impact on dividends and bailout probability. Overall, we therefore conclude that the decline in market capitalization is most consistent with a reduction in bank profitability.[26]

How big is the reduction in return on assets? The coefficient estimate implies that the (annualized) RoA for EBA banks is on average approximately 27 basis points lower after the EBA capital exercise is initiated. Compared to a pre-EBA (end of 2010) average (annualized) RoA of 50 basis points, the point estimate therefore implies that RoA for EBA banks fell by roughly 55 % during the capital exercise. A rough back-of-the-envelope calculation of how much this decline in RoA can explain of the decline in market capitalization suggests that approximately 30 % of the decline in market capitalization can be explained by the reduction in bank profitability.[27]

[26] Note that a reduction in RoA does not necessarily imply a reduction in profitability per se. Higher capital ratios could lead to a lower required return on loans and hence induce banks to extent marginally less profitable loans. Note, however, that this would imply an increase in net income. Hence, the coefficient estimate in column 5 of Table 2 is a more direct way to estimate the impact on profitability.

[27] Specifically, we calculate this number by using a dividends growth formula, i.e., we assume that the stock price of a bank is given by $P = \frac{D}{r}$ where P is the stock price, D is future dividends and r is the effective discount rate, i.e., the difference between the cost of equity and the growth rate of dividends. Normalizing the number of shares to 1, this formula allows us to decompose how changes in dividends affect changes in market capitalization. We use pre-EBA data on dividends and market cap to calibrate a $r = 0.03$. We then assume a fixed dividend share of 34% of net income, equal to the pre-EBA median payout ratio of EBA banks. Moreover, we assume that this payout ratio is fixed in line with the estimates from Table 2. Armed with these assumptions, we use the estimated drop in net income from the last column in Table 2 to back out an implied drop in market capital. The drop implied drop in market capital is equal to $dP = \frac{0.34 \times (-0.410)}{0.03} = -4.6$ billion EUR. The observed drop in the level of market capital

VI. Policy Implications

The empirical analysis in this paper has documented that an increase in capital requirements leads to an increase in bank risk without reducing market assessment of implicit and explicit government guarantees. From a policy perspective, a crucial question is therefore whether there are other policies that are more efficient in terms of reducing banks' risk. Two papers, focusing on the impact of alternative interventions on systemic risk, are especially relevant for this purpose.

Berger et al. (2020) analyze the effect of participation in the U.S. TARP on systemic risk measures. In relation to this, Nistor Mutu and Ongena (2018) analyze the effects on systemic risk for a set of international episodes of recapitalizations, liquidity injections, and public guarantees.[28] A broad conclusion from both papers is that pure recapitalizations *decrease* systemic risk. Hence, a tentative conclusion from these papers and the analysis we present is that directed recapitalization is more effective in terms of reducing bank risk, compared to increased capital requirements.[29] This provides novel support for the key principles of bank capital regulation outlined in Greenwood et al. (2017), which emphasizes the need to regulate capital rather than capital ratios, especially after adverse shocks.

A key challenge is that, even though public recapitalizations are potentially successful in terms of reducing bank risk, banks' raise too little capital during a downturn if left to their own devices (Sarin and Summers, 2016). One potential explanation for this is equity/dividend signaling (Juelsrud and Nenov, 2019).[30] In that case, policies which force private recapitalizations such as

is approximately 16 billion EUR. We therefore conclude that the implied drop in market cap due to a drop in net income can account for ca. $\frac{-4.6}{-16} = 29\%$.

[28]For example, Bayazitova and Shivdasani (2012) provide evidence that banks with higher management compensation were less likely to apply for TARP funding, i.e., there was a possible self-selection, or even get rejected more frequently.

[29]Why is a recapitalization like TARP more successful in terms of reducing systemic risk compared to the EBA capital exercise? A few key differences between TARP and the EBA capital exercise are worth highlighting. First, banks that applied for the Capital Purchase Program (CPP) as part of TARP received an equity injection from the government in order to increase their capital levels to comply with respective regulations. In our setting, banks are left with several options to comply with required capital levels. As Gropp et al. (2019) and we show, EBA banks reduce risky lending in order to shrink asset size rather than raising capital. This in turn have implications for the value of bank capital. Second, Bayazitova and Shivdasani (2012) show that distressed U.S. banks that applied for TARP had a generally high asset quality and that participation in the program had a positive effect after respective stress test results ("SCAP") had been released. We do not observe similar "certification effects" for EBA banks. Third, due to the nature of the CPP, the U.S. government owned preference shares of participating banks and thus, played a major role in monitoring bank activities as a shareholder. This is not the case in the EBA capital exercise where governments and regulators were more passive.

[30]According to this view, banks are reluctant to privately raise capital by cutting dividends or issuing equity during a liquidity crisis due to asymmetric information between short-term lenders and the bank. In a such setting,

dividend restrictions or policies that fosters public recapitalization such as direct equity injections can improve financial stability.

VII. Conclusion

In this paper, we use the EBA capital exercise of 2011 as a quasi-natural experiment to investigate how capital requirements affect various measures of bank solvency risk. We show that while regulatory measures of solvency improve, non-regulatory measures show, if anything, a deterioration in bank solvency in response to higher capital requirements. This decline in bank solvency is driven by a decline in the banks' market value of equity. When exploring the channels behind our findings, we conclude that EBA bank stock devaluations are most consistent with a reduction in bank profitability, rather than a repricing of bank equity due to a reduction of implicit and explicit too-big-too-fail guarantees.

Our paper suggests that the overall judgment as to whether higher capital requirements improve solvency is less obvious than perhaps initially thought. An important avenue for future research is to consider the impact of other post-crisis policy measures on bank risk, such as liquidity requirements. It is possible that the liquidity and funding regulation that has accompanied higher capital requirements have made the financial system less fragile. In order to shed light on the overall impact of post-crisis capital and liquidity requirement on the fragility of the financial system, further research is required.

raising capital can precipitate a liquidity crisis, as it is interpreted as bad news by short-term lenders. Because of this, banks can potentially pay too much dividends or issue too little equity during a liquidity crisis from a social point of view.

References

Acharya, V., R. Engle, and D. Pierret (2014): "Testing macroprudential stress tests: The risk of regulatory risk weights," *Journal of Monetary Economics*, 65, 36–53.

Acharya, V. V., A. N. Berger, and R. A. Roman (2018): "Lending implications of U.S. bank stress tests: Costs or benefits?" *Journal of Financial Intermediation*, 34, 58–90.

Acharya, V. V., R. F. Engle, and M. Richardson (2012): "Capital Shortfall: A New Approach to Ranking and Regulating Systemic Risks," *American Economic Review: Papers and Proceedings*, 102, 59–64.

Acharya, V. V., L. H. Pedersen, T. Philippon, and M. Richardson (2017): "Measuring Systemic Risk," *Review of Financial Studies*, 30, 2–47.

Adrian, T. and M. K. Brunnermeier (2016): "CoVaR," *American Economic Review*, 106, 1705–1741.

Aiyar, S., C. W. Calomiris, J. Hooley, Y. Korniyenko, and T. Wieladek (2014a): "The international transmission of bank capital requirements: Evidence from the UK," *Journal of Financial Economics*, 113, 368–382.

Aiyar, S., C. W. Calomiris, and T. Wieladek (2014b): "Does Macro-Prudential Regulation Leak? Evidence from a U.K. Policy Experiment," *Journal of Money, Credit and Banking*, 46(1), 181–214.

——— (2016): "How Does Credit Supply Respond to Monetary Policy and Bank Minimum Capital Requirements?" *European Economic Review*, 82, 142–165.

Bahaj, S. and F. Malherbe (2020): "The Forced Safety Effect: How Higher Capital Requirements Can Increase Bank Lending," *The Journal of Finance*.

Baker, M. and J. Wurgler (2015): "Do Strict Capital Requirements Raise the Cost of Capital? Bank Regulation, Capital Structure, and the Low-Risk Anomaly," *American Economics Review: Papers & Proceedings*, 105(5), 315–320.

Bayazitova, D. and A. Shivdasani (2012): "Assessing TARP," *Review of Financial Studies*, 25, 377–407.

Benoit, S., G. Colletaz, C. Hurlin, and C. Pérignon (2014): "A Theoretical and Empirical Comparison of Systemic Risk Measures," Working Paper.

Berger, A. N., R. A. Roman, and J. Sedunov (2020): "Did TARP Reduce or Increase Systemic Risk? The Effects of Government Aid on Financial System Stability," *Journal of Financial Intermediation*, 43.

Berrospide, J. M. and R. M. Edge (2019): "The Effects of Bank Capital Buffers on Bank Lending and Firm Activity: What Can We Learn from Five Years of Stress-Test Results?" *Finance and Economics Discussion Series*.

Bhattacharya, S. (1979): "Imperfect information, dividend policy, and 'the bird in the hand' fallacy," *The Bell Journal of Economics*, 259–270.

Bogdanova, B., I. Fender, E. Takáts, et al. (2018): "The ABCs of bank PBRs," *BIS Quarterly Review*, 81.

Bostandzic, D. and G. N. Weiss (2018): "Why do some banks contribute more to global systemic risk?" *Journal of Financial Intermediation*, 35, 17–40.

Bouwman, C. H., S. Hu, and S. A. Johnson (2018): "Differential bank behaviors around the Dodd–Frank Act size thresholds," *Journal of Financial Intermediation*, 34, 47–57.

Brownlees, C. T. and R. Engle (2017): "SRISK: A Conditional Capital Shortfall Measure of Systemic Risk," *Review of Financial Studies*, 30(1), 48–79.

Célérier, C., T. Kick, and S. Ongena (2018): "Taxing Bank Leverage: The Effects on Bank Capital Structure, Credit Supply and Risk-Taking," Working paper.

Chousakos, K. T. and G. B. Gorton (2017): "Bank health post-crisis," NBER Working paper.

Cortés, K. R., Y. Demyanyk, L. Li, E. Loutskina, and P. E. Strahan (2020): "Stress tests and small business lending," *Journal of Financial Economics*, 136, 260–279.

D'Acunto, F. and A. Rossi (forthcoming): "Regressive Mortgage Credit Redistribution in the Post-crisis Era," *Review of Financial Studies*.

Degryse, H., A. Karapetyan, and S. Karmakar (2018): "To Ask or Not To Ask? Bank Capital Requirements and Loan Collateralization," Working Paper.

Engle, R. (2002): "Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models," *Journal of Business and Economic Statistics*, 20(3), 339–350.

——— (2018): "Systemic Risk 10 Years Later," *Annual Review of Financial Economics*, 10, 125–152.

Fraisse, H., M. Lé, and D. Thesmar (2017): "The real effects of bank capital requirements," Working Paper.

Gao, Y., S. Liao, and X. Wang (2018): "Capital markets assessment of the economic impact of the Dodd Frank Act on systemically important financial firms," *Journal of Banking & Finance*, 86, 204–223.

Gehrig, T. and M. C. Iannino (2018): "Capital regulation and systemic risk in the insurance sector," *Journal of Financial Economic Policy*, 10, 237–263.

Greenwood, R., S. G. Hanson, J. C. Stein, and A. Sunderam (2017): "Strengthening and Streamlining Bank Capital Regulation," Brooking Papers on Economic Activity.

Gropp, R., H. Hakenes, and I. Schnabel (2011): "Competition, Risk-shifting, and Public Bail-out Policies," *Review of Financial Studies*, 24(6), 2084–2120.

Gropp, R., T. Mosk, S. Ongena, and C. Wix (2019): "Banks Response to Higher Capital Requirements: Evidence from a Quasi-Natural Experiment," *Review of Financial Studies*, 32(1), 266–299.

Haldane, A. G. and V. Madouros (2012): "The dog and the frisbee," *Revista de Economía Institucional*, 14, 13–56.

Hou, K., G. A. Karolyi, and B.-C. Kho (2011): "What Factors Drive Global Stock Returns?" *Review of Financial Studies*, 24(8), 2527–2574.

Ince, O. and R. Porter (2006): "Individual Equity Return Data From Thomson Datastream: Handle With Care!" *Journal of Financial Research*, 29, 463–479.

Jiménez, G., S. Ongena, J.-L. Peydró, and J. Saurina (2017): "Macroprudential policy, countercyclical bank capital buffers, and credit supply: Evidence from the Spanish dynamic provisioning experiments," *Journal of Political Economy*, 125(6), 2126–2177.

Juelsrud, R. and E. G. Wold (2020): "Risk-weighted capital requirements and portfolio rebalancing," *Journal of Financial Intermediation*, 41.

Juelsrud, R. E. and P. T. Nenov (2019): "Dividend Payouts and Rollover Crises," *The Review of Financial Studies*.

Kelly, B., H. Lustig, and S. Van Nieuwerburgh (2016): "Too-Systemic-to-Fail: What Option Markets Imply about Sector-Wide Government Guarantees," *American Economic Review*, 106, 1278–1319.

Kisin, R. and A. Manela (2016): "The shadow cost of bank capital requirements," *Review of Financial Studies*, 29, 1780–1820.

Krahnen, J.-P., F. Noth, and U. Schüwer (2017): "Structural Reforms in Banking: The Role of Trading," *Journal of Financial Regulation*, 66–88.

Liikanen, E. (2012): "High-level Expert Group on reforming the structure of the EU banking sector," Brussels, 2 October 2012.

Löffler, G. and P. Raupach (2018): "Pitfalls in the Use of Systemic Risk Measures," *Journal of Financial and Quantitative Analysis*, 53(1), 269–298.

Mésonnier, J.-S. and A. Monks (2015): "Did the EBA capital exercise cause a credit crunch in the Euro area?" *International Journal of Central Banking*, June 2015, 75–117.

Mora, R. and I. Reggio (2012): "Treatment effect identification using alternative parallel assumptions," Working paper.

Nistor Mutu, S. and S. Ongena (2018): "The Impact of Policy Interventions on Systemic Risk across Banks," Working paper.

Noss, J. and R. Sowerbutts (2012): "The Implicit Subsidy of Banks," Bank of England Financial Stability Paper No. 15.

Rabemananjara, R. and J.-M. Zakoïan (1993): "Threshold ARCH models and asymmetries in volatility," *Journal of Applied Econometrics*, 8, 31–49.

Sarin, N. and L. Summers (2016): "Understanding Bank Risk through Market Measures," *Brookings Papers on Economic Activity*, Fall, 57–109.

Schäfer, A., I. Schnabel, and B. Weder di Mauro (2016): "Financial Sector Reform after the Subprime Crisis: Has Anything Happened?" *Review of Finance*, 20(1), 77–125.

Schmidt, C. (2019): "Bank Leverage, Capital Requirements and the Implied Cost of (Equity) Capital," Working Paper.

Yellen, J. (2018): "Keynote adress from Janet Yellen on the tenth anniversary of the financial crisis," *Brookings*.

Zhang, Q., F. Vallascas, K. Keasey, and C. Cai (2015): "Are Market-Based Measures of Global Systemic Importance of Financial Institutions Useful to Regulators and Supervisors?" *Journal of Financial and Quantitative Analysis*, 47(7), 1403–1442.